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(71) Applicant:
Van Doorne's Transmissie B.V.
NL-5026 RA Tilburg (NL)

(72) Inventors:
- **Brandsma, Arjen**
  5045 WN Tilburg (NL)
- **Van Lith, Johannes Hendrikus**
  5258 PL Berlicum (NL)
- **Van der Meer, Cornelis Johannes Maria**
  5042 CV Tilburg (NL)
- **Van der Kamp, Johannes Haaije**
  5045 WN Tilburg (NL)
- **Van Oirschot, Cornelus Hendricus Maria**
  5015 AE Tilburg (NL)
- **Van Dijnsen, Gerardus Petrus Maria**
  5641 NA Eindhoven (NL)

(54) **Metal belt and method for producing such**

(57) The invention relates to a drive belt (1), in particular according to claim 1 or 2, for a continuous variable transmission comprising at least one endless metal band (2), preferably provided in a set of nested bands, at least partly being surrounded by transverse elements(3) for at least clamping the belt (1) in between the sheaves of a set of pulleys (4, 5). At least one band (2) is shaped such, as seen in cross section, that the arithmetical relation between thicknesses TA, TB and TC at three points PA, PB, PC on a contact face (6-9), given by the formula (1- (TA+TB)/2TC) represents a value greater than 0.001 and smaller than 0.100, wherein points PA, PB and PC are indicative of a substantially transverse line relative to the longitudinal direction of the band, wherein point PC is located between PA and PB, wherein points PA and PB are located near the edge of the band.

FIG. 3

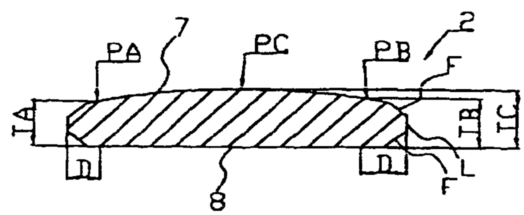
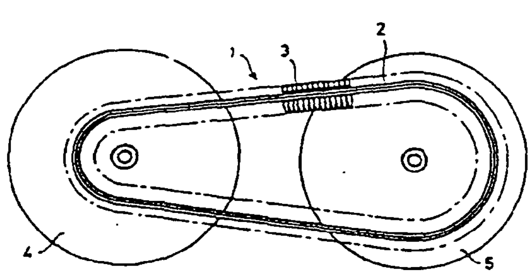


FIG. 1



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Description

[0001] The present invention relates to a metal belt for a continuously variable transmissions and a method for producing such, where, as described in the preamble of claim 1, the belt comprises at least one endless metal band, preferably provided in a set of generally conforming nested bands, at least partly being surrounded by transverse elements for at least clamping the belt in between the sheaves of a set of pulleys.

[0002] Such a metal belt is generally known, e.g. from US pat. Spec. 3.949.621. The bands of this known construction have a generally rectangular cross section. Due to its nature of use in continuously variable transmissions, the known belt is during operation subjected to extremely high internal stresses varying in height with the radius of bending and with the moment transmitted or the pull force in a band resulting there from. For this reason avoidance of breakage of the belt during the service life of a belt, i.e. the transmission and vehicle wherein it is to be applied, is a main point of consideration with such belts, in particular with the bands of a belt.

[0003] One technical measure intended for prolonging service life is known from European patent publication EP-B-181670. This document teaches to provide permanent compression stresses in the central and edge part of the contact faces of the bands of the belt, thus resulting in a reduction of the level of locally occurring tensile stresses. The publication further teaches the deformation of the edge zones towards a confined shape so as to reduce tensile stresses, particularly occurring from bendings, as a result of which breakage caused by hairline cracks occurring from the edges would be largely avoided.

[0004] The present invention seeks to provide at least a further if not an alternative solution in raising belt service life. According to the invention this may be achieved by accurately defining the geometry of a bands cross-section as is indicated in the characterising portion of claim 1. Bands according to the present invention show extremely small though measurable differences in the thickness along a cross section of a band. It was found in practise however, that the overall shape of a cross section influences the said service life time of a belt, to the extend that extremely small deviations from an imaginary rectangular cross section of a band account for significant influence on the expected service life time of a belt.

[0005] One factor mentioned to explain the above effect is that a band shaped according to the invention provides a certain amount of precompensation for so called anticlastic deformation occurring during the operation of a belt. However, the local differences in diameter of bending caused by anticlastic deformations hardly effects increase in internal strain as may be expected locally in a band. Moreover, a full precompensation of this effect, for as far as might be achieved, would require a thickness ratios between TA and TC or TB and TC of about 0.5. Nevertheless the minimal amount of deviation from an imaginary cross section, according to the invenvention realises a significant increase in expected life time, and may advantageously be realised by a shaping roller having a relatively easy to produce conformingly shaped roller surface.

[0006] It is remarked that anticlastic deformation per se is a generally known phenomenon, e.g. from the article "an optimum study of the anticlastic deformations of strips with tapered edges" as published in the int. Journal of Mechanical Science , 1966, vol. 8. For compensating for anticlastic deformation, this article teaches to concentrate on tapering configuration of the edges. The present invention however differs from these known strip shapes in that the contact face of a band shows a deviation from a flat surface and in that the invention is related to the overall shape of a bands cross section of minimal order. Also, the general art does not take account of the function of taking up extremely high tensile forces as inherent to a bands function, nor of the material a band or strip is made of.

[0007] Further, from the article "Hypergeometric Series Solutions of some Anticlastic Deformation Problems", by Y.C. Pao et.al., published in 1967, a strips cross section is known, the section being defined such that the local thickness is a function of the greatest thickness of the strip and the lateral displacement from a strips centre, such that the thickness of a strip constantly decreases from its greatest thickness in the centre towards zero thickness at a lateral side of the strip. The article is primarily devoted to the mathematical solutions to the problem of anticlastic deformations.

[0008] With the present invention the edge zones may comprise ordinary facet rounding or leveling of square edges, as generally known in the art. Measuring of the thickness of a bands edge position should take place beyond such rounding. Normally half a millimetre length away from the edge will provide sufficient distance to such rounding while still being close to the outer edge.

[0009] Preferably, a band has a cross section of such shape, that the flat surfaces of contact faces of a band have a smoothly curved surface. In a further development of the geometry according to the invention the thickness in between the two edges of a band is larger than the thickness of any of these. Yet according to a further feature according to the invention, the largest thickness is located substantially centrally in the middle between the edges. In the most preferred embodiment said surface of the band is of elliptical nature. This geometry according to the invention approximates, at least, or is enclosable by circular sections having radi R1 and R2, such that the difference between 1/R1 and 1/R2 is smaller than 1.0 m^{-1}, where R1 is the radius for the ellipse of one side face, and wherein R2 is the ellipse radius of the counter side. Where both faces are shaped convexely the sum of 1/R1 and 1/R2 should be smaller than 1.0 m^{-1}.

[0010] The invention will now further be explained by way of examples given in the accompanying drawing wherein:

Figure 1 is a schematic illustration of the transmission and belt the present invention relates to;
Figures 2-4 indicate possible geometries of a cross section of a band according to the invention;
Figure 5 is a plot indicating the relation between the geometry according to the invention and the to be expected service lifetime of the belt.

[0011] Figure 1 shows schematically a continuous variable transmission (CVT) with a conveyor belt 1 which is made up of endless thin bands 2, and on which there are an endless continuous series of cross elements 3 which slide freely there over. They move between the sheaves of pulleys 4 and 5, with steplessly variable diameter. Such a continuous variable transmission is known per se. Typical thicknesses of a band range from 0.15 to 0.20 mm. Typical widths of a band range from 8 to 35 millimeters. Typical circumferential lengths of a drive belt 1 range from 50 to 100 cm. For reasons of economical production and for preventing technical complexity, a belt usually runs between pulleys 4, 5 of which only one sheave is arranged axially movable, while the other is arranged rotationally and axially fixed to an axle of rotation. This arrangement means that during operation the alignment of a belt 1 and its bands 2 deviates from the ideal position orthogonal to the axles of rotation. For coping with this "mis-alignment" the contact faces of the transverse elements against which the inner bands rests are provided with a slightly convex curvature.

[0012] Figure 2 shows a cross section of a band 2 according to the invention, wherein one contact face is of planar configuration. The other, e.g. outer, contact face 6 shows an in between part taking up between one third and two thirds of the face surface, and is protruded to a larger extend than the lateral portions of the contact face 6. The edges of the band 2 are rounded off by schematically represented facet roundings or levelings F, as usual in the art. The lateral sides L of a band 2 are shaped flat and have a height TC minus the amount of decrease in thickness in lateral direction and minus the height of facet roundings F.

[0013] As indicated in figure 3, thicknesses TA and TB of the lateral positions of a band 2 should, for purposes of indicating the configuration of contact faces according to the invention, be measured closest at points PA and PB to the lateral sides L, however beyond the facet roundings F. Typically, a transverse distance D of between 0.5 and 1.0 millimeter provides a good measuring point. Measuring should take place along an imaginary transverse line relative to the longitudinal direction of a band, and generally square to the imaginary plane that can be imagined more or less centrally between both contact faces of a band. A thickness TC should according to the invention be measured at some point between points PA and PB on or in the immediate vicinity of said imaginary transverse line. The thicknesses in dimensionless index BI, calculated by the formula (1 - (A+B)/2C) should lead to a value greater than zero. It is remarked that according to the invention TA, TB and TC may differ significantly provided that TA, TB and TC satisfy the given formula. For achieving a sufficient degree of accuracy, measuring of TA, TB and TC should take place at least five times, each time on a different location on a band, mutually displaced at least one centimeter. A so called mara-meter may be used. The formula for index BI, in conformance with the invention shows that one lateral side may be thicker than the other.

[0014] Figure 4 schematically represents an embodiment where inner and outer contact face 7 and 9 are both convexely shaped. Preferably but not necessarily both contact faces are curved according to a circular section having diameters R1 and R2 respectively. The radi R1 and R2 may be of equal length. Preferably the centre of the radi R1 and R2 are both located on a common, imaginary line at a generally right angle to a contact face 7 or 9, and located in the centre thereof. For achieving a favourable geometry, according to the invention, the sum of 1/R1 and 1/R2 should be greater than 1.0 m^{-1}. In the present example one contact face shows a decrease by 1 micrometer from TC to TA or TB, where as the other shows a decrease of 2 micrometer. In a preferred embodiment the both sides are shaped with a substantially similar amount of decrease towards the edges L.

[0015] Figure 7 is an illustration of the correlation found between the distribution of thickness over a bands cross section, represented above given formula along axis X and the expected service lifetime of the belt along axis Y. In the graph the zero line for X represents a perfectly rectangular shape of a bands cross section. To the left of this axis the index BI, (1-(TA+TB)/2TC), for the thickness distribution as explained above increases. To the right of this X = 0 line the index represents the amount of the inverse shape, i.e. the amount by which the lateral sides of a band are thicker than the middle portion thereof. Upwardly along the Y-axis an index for expected life time is indicated, e.g calculated on the basis of number of revolutions of a belt 1 within a pulley assembly in one or more certain rations.

[0016] According to the invention it was found for belts of the above described typical dimensions, that within the range of indexes, BI = (1 - (TA+TB/2TC)) , between 0.001 and 0.1, the relationship between the index BI as the expected service live is to a significant degree linear and accounts for a significant influence on belt service life. This is in the graph shown by a regression line represented in bold in between dotted lines, the dotted lines representing the boundaries for the location and angle of highly probable regression lines. For increasing values of the index BI at both sides of BI=0, the relation-

ship becomes non linear. The graph nevertheless is indicative of the finding that within the specified range significant increase in service lifetime is achieved by an extremely small, though practically measurable raise of at least part of a contact face, located between the edge parts.

[0017] The invention further relates to all details indicated in the following claims and figures.

Claims

1. Drive belt (1) for a continuous variable transmission, comprising at least one endless metal band (2), preferably provided in a set of nested bands, at least partly being surrounded by transverse elements (3) for at least clamping the belt (1) in between the sheaves of a set of pulleys (4, 5), characterised in that, a band (2) is provided with a central portion, as seen in cross section, having a minimal but consistant degree of greater thickness than a lateral portion.

2. Drive belt (1), in particular according to claim 1, for a continuous variable transmission comprising at least one endless metal band (2), preferably provided in a set of nested bands, at least partly being surrounded by transverse elements (3) for at least clamping the belt (1) in between the sheaves of a set of pulleys (4, 5), characterised in that a band (2), as seen cross wise, shows a continuous, preferably smooth, decrease of thickness from at least immediately near the centre of a band towards the lateral sides of the band (2).

3. Drive belt (1), in particular according to claim 1 or 2, for a continuous variable transmission comprising at least one endless metal band (2), preferably provided in a set of nested bands, at least partly being surrounded by transverse elements(3) for at least clamping the belt (1) in between the sheaves of a set of pulleys (4, 5), characterised in, that at least one band (2) is shaped such, as seen in cross section, that the arithmetical relation between thicknesses TA, TB and TC at three points PA, PB, PC on a contact face (6-9), given by the formula (1- (TA+TB)/2TC) represents a value greater than 0.001 and smaller than 0.100, wherein points PA, PB and PC are indicative of a substantially transverse line relative to the longitudinal direction of the band, wherein point PC is located between PA and PB, wherein points PA and PB are located near the edge of the band.

4. Drive belt (1) according to claim 1, 2 or 3 wherein point PC is located substantially centrally between PA and PB.

5. Drive belt (1) according to any of the preceding claims, characterised in, that thickness TC is greater than any of the thickness TA and TB.

6. Drive belt (1) according any of the preceding claims, characterised in that, the cross wise decrease in thickness from the centre of the band towards it's side is greater than or equal to 2 µm and smaller than or equal to 20 µm, the bandwidth being between 8 and 35 millimeter.

7. Drive belt (1) according to any of the preceding claims characterised in, that the band (2) is substantially symmetrically shaped in respect of an imaginary plane located centrally between the contact faces (6-9) of a band (2).

8. Drive belt (1) according to any of the preceding claims, characterised in, that the band (2) is substantially symmetrically shaped in respect of an imaginary plane located centrally between the lateral faces (L) of the band (2).

9. Drive belt (1) according to any of the preceding claims characterised in, that thicknesses TA and TB are measured in the immediate vicinity of an ordinary facet rounding (F).

10. Drive belt (1) according to any of the preceding claims wherein the thicknesses TA, TB and TC are the mean of five measurements on longitudinally displaced locations on the band (2).

11. Drive belt (1) according to any of the preceding claims characterised in, that at least one contact face (6-9) is in cross direction of the band (2), smoothly curved.

12. Drive belt (1) according to claim 11, characterised in, that the curvature defines, approximates, or is enclosable by a circular radius (R1, R2) greater than one metre.

13. Drive belt (1) according to claim 12, characterised in, that both contact faces are shaped convexely, such that $1/R1 + 1/R2 \leq 1.0\ m^{-1}$, wherein R1 and R2 are the radi associated with each contact surface (7, 9).

14. Drive belt (1) according to any of the preceding claims characterised in, that the band (2) is made of a so called maraging type of steel.

15. Drive belt (1) according to any of the preceding claims characterised in, that at least the inner of a number of nested bands (2) is shaped according to any of the preceding claims.

16. Drive belt (1) according to any of the preceding

claims characterised in, that the majority of the bands (2) of a belt (1) are shaped according to any of the preceding claims.

17. Drive belt (1) according to any of the preceding claims characterised in, that all bands (2) of a belt (1) are shaped according to any of the preceding claims.

18. Method for producing a band (2) for a drive belt (1) for a continuous variable transmission, in particular as defined in any of the preceding claims, comprising the steps of deforming the band (2) by leading the band (2) between the surfaces of two, preferably rotating deformation elements such as rollers, adapted for creating a bands contact face (6-9) correspondingly to a band (2) defined in any of the preceding claims, subsequently annealing the band (2) and thereafter heating the band (2) in a nitrogen environment for chemically creating a superficial permanent compression layer known per se.

FIG. 1

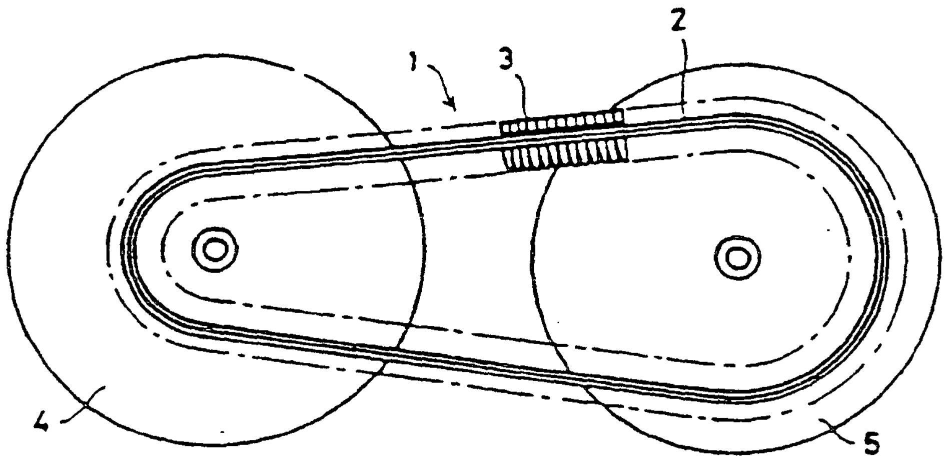


FIG. 2

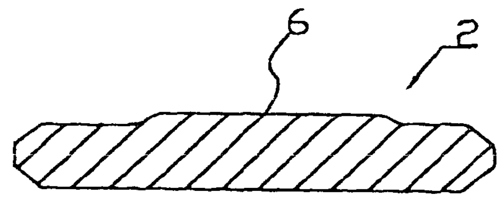


FIG. 3

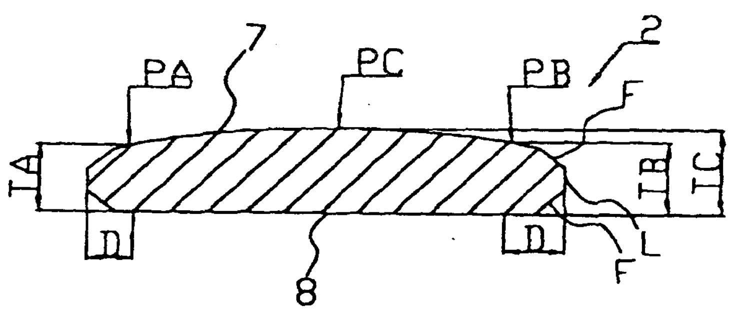


FIG. 4

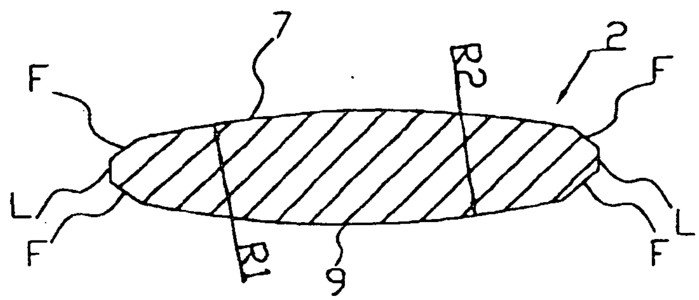
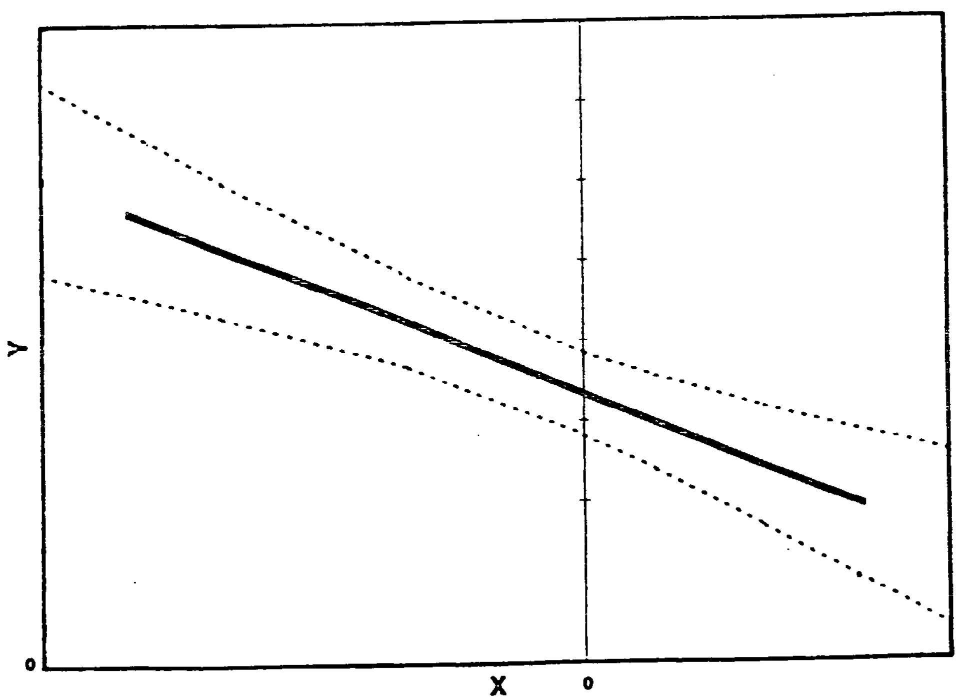


FIG. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 98 20 1210

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	PATENT ABSTRACTS OF JAPAN vol. 11, no. 158 (M-591), 22 May 1987 & JP 61 290257 A (NISSAN MOTOR CO. LTD.), 20 December 1986 * abstract *	1,2,5,8, 11,15-17	F16G5/16 B21D53/14
X	PATENT ABSTRACTS OF JAPAN vol. 010, no. 238 (M-508), 16 August 1986 & JP 61 070245 A (NISSAN MOTOR CO LTD), 11 April 1986 * abstract *	1,5	
Y,D	US 3 949 621 A (BEUSINK) 13 April 1976 * the whole document *	1,5,7,8	
Y,D	EP 0 181 670 B (VAN DOORNE'S TRANSMISSIE B.V.) 4 January 1989 * page 3, line 51 - line 65; figure 4 *	1,5,7,8	
A		18	
A	US 4 698 050 A (HATTORI) 6 October 1987 * column 4, line 46 - column 5, line 32 *	14,18	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US 5 152 723 A (HERBERT) 6 October 1992 * column 1, line 11 - line 12 * * column 1, line 62 - column 2, line 11 *	18	F16G B21D
A	PATENT ABSTRACTS OF JAPAN vol. 008, no. 187 (C-240), 28 August 1984 & JP 59 080772 A (TOYOTA JIDOSHA KK), 10 May 1984 * abstract *	14,18	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	1 September 1998	Baron, C

CATEGORY OF CITED DOCUMENTS

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